DIABLO CANYON POWER PLANT

Event Investigation Report 2006-001

Nonconformance Report N0002214

UNIT 2 REACTOR TRIP AND UNUSUAL EVENT DUE TO CWP 2-1 FAULT

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Executive Summary

On December 12, 2006, at 1322 PST, while conducting power ascension operations with Unit 2 at approximately 25 percent power, an electrical failure occurred in the Unit 2 circulating water pump motor enclosure (CWP) 2-1. A loud bang and explosion was reported to the Unit 2 control room. At 1322 PST, an electrical transient was experienced on Unit 2 12-kV non-vital bus 'D' which in turn caused reactor coolant pump (RCP) 2-2 and RCP 2-4 motor breakers to trip on 12kV non-vital bus 'D' undervoltage, initiating an automatic reactor trip. The reactor trip signal was initiated when 2 out of 4 RCP motor breakers opened. All control rods fully inserted in response to the reactor trip and all plant systems functioned as required. The auxiliary feedwater system for Unit 2 was manually actuated per plant procedures, before an auto-start signal for this system was generated. At 1356 PST, DCPP Fire Department first responders reported that the fire was out.

At 1340 the Operations declared a Notice of Unusual Event (NUE), number 23, 'Confirmed Explosion Onsite.'

The auxiliary feedwater system was put in service to remove decay heat from the steam generators steaming to the atmospheric dump valves. Electrical power is being supplied via offsite power.

Unit 2 was stabilized Mode 3. There were no injuries associated with this event. DCPP Unit 1 was unaffected and remained in Mode 1 at 100% power.

The Unusual Event was terminated at 1430 PST after confirming the damage was limited to the circulating water pump motor terminals and that the explosion was caused by an electrical fault. The fire brigade confirmed the fire was extinguished and that the damage was confined to the local area of circulating water pump 2-1.

The apparent cause of the electrical fault was determined to be a failed surge capacitor at the 12 kV junction box on CWP 2-1.

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1. Sequence of Events

Date	Time	Event Description	Source
05/23/06	10:26	52VD5 closed, CWP 2-1 started towards end of 2R13 outage.	OPS Log
12/10/06	15:51	52VD5 opened, CWP 2-1 secured after manual Unit Trip (12kV busses D and E transferred to Startup Power with CWP 2-2 selected for auto-reclose).	OPS Log
12/11/06	03:05 (approx.)	12kV bus D and E transferred from Startup to Aux Power.	OPS Log
12/11/06	16:58	52VD5 closed, CWP 2-1 started for pick and dredge of CWP 2-2 waterbox.	OPS Log
12/11/06	21:03	Secured CWP 2-2 for waterbox pick and dredge.	OPS Log
12/12/06	03:41 (approx.)	12kV bus D and E transferred from Aux to Startup Power.	OPS Log
12/12/06	11:05	Unit 2 paralleled to grid.	OPS Log
12/12/06	12:42	Unit 2 completed ramp to 150MWe.	
12/12/06	12:49	Unit 2 started ramp to 28% power (240MWe target).	OPS Log
12/12/06	13:15 (approx.)	Operators transfer 4kV busses F, G, H, D, and E from Startup to Aux Power. SUT 2-1 LTC is in manual to match voltages for transfers.	Personnel statements and interviews
12/12/06	13:22 (approx)	Operators transfer 12kV bus E from Startup to Aux Power. NOTE: Bus D and the operating CWP 2-1 are still supplied from Startup Power. Approximately 1 or 2 seconds after transferring 12kV bus E from Startup to Aux Power, Unit 2 reactor trips.	Personnel statements and interviews
12/12/06	13:22:09.810	T = 0 sec - 12kV Startup Transformer 2-1 ground overcurrent alarm	Main Annunciator
12/12/06	13:22:09.849	T + 0.039 sec - 4kV Bus D Startup Feeder UV Alarm	Main Annunciator
12/12/06	13:22:09.850	T + 0.040 sec - 4kV Bus E Startup Feeder UV Alarm	Main Annunciator
12/12/06	13:22:09.859	T + 0.049 sec - 12kV Bus D UV Trip Alarm	Main Annunciator

12/12/06	13:22:09.872	T + 0.062 sec - CWP 2-1 Differential Trip Alarm	Main Annunciator
12/12/06	13:22:09.873	T + 0.063 sec - CWP 2-1 OC Trip Alarm	Main Annunciator
12/12/06	13:22:09.894	T + 0.084 sec - Condenser not Available C-9 Alarm	Main Annunciator
12/12/06	13:22:09.913	T + 0.103 sec - RCP 2-2 Breaker Open Alarm	Main Annunciator
12/12/06	13:22:09.914	T + 0.104 sec - RCP 2-4 Breaker Open Alarm	Main Annunciator
12/12/06	13:22:09.916	T + 0.106 sec - RCP Breaker Open or Low Flow and P-7 2/4 Reactor Trip Alarm	Main Annunciator
12/12/06	13:22:09.980	T + 0.170 sec - Unit 2 Reactor Trip Alarm	Main Annunciator
12/12/06	13:22:41.710	T + 31.900 sec - Unit Trip Alarm	Main Annunciator
12/12/06	13:22:41.714	12kV Bus-E Auto Xfer Alarm. NOTE:	Main Annunciator
12/12/06	13:22:41.721	4kV Bus-H Auto Xfer Alarm	Main Annunciator
12/12/06	13:22:41.722	4kV Bus-F Auto Xfer Alarm	Main Annunciator
12/12/06	13:22:41.723	4kV Bus-G Auto Xfer Alarm	Main Annunciator
12/12/06	13:22:41.733	Gen PCB 542 Trip	Main Annunciator
12/12/06	13:22:41.743	Gen PCB 642 Trip	Main Annunciator
12/12/06	13:22:41.756	4kV Bus-E Auto Xfer Alarm	Main Annunciator
12/12/06	13:22:41.757	4kV Bus-D Auto Xfer Alarm	Main Annunciator

2. Engineering Event Evaluation

The following events were reviewed against PPC and TRS data, and Control Room logs.

Operator performed a Unit 2 Bus “E” transfer from S/U power to Auxiliary power. This event did not result in bus voltage or current changes outside of expected values for bus “E”

Alarms received in the Control Room for Unit 1, associated with Unit 2 Bus transfer. These alarms received in the past based on changes to S/U Transformer loading. PPC data does not indicate a problem with Unit 1 equipment powered from S/U.

Review of voltage and current on Unit 2 Bus “D” does not indicate a problem associated with the Bus “E” transfer to Aux. Power.

Main annunciator alarm, 12kV S/U Transformer ground over current alarm. This relay initiates on 1 amp of sensed ground current. Engineering supports this as a valid indication of a problem somewhere on the 12 kV system powered from S/U.

Alarms indicating under voltage on 4kV Bus “D” Start-up Feeder and 4kV Bus “E” Start-up Feeder. This indication is abnormal for the electrical line-up and indicated a drop in S/U voltage

There are multiple undervoltage relays associated with the bus. After review of the undervoltage scheme revealed that the 12kV Bus “D” undervoltage scheme operated per design. This design review was performed using drawing 441350. The review of the schematic identified a circuit in the schematic that instantaneously trips the load breakers on 12kv Bus "D". This circuit is connected to the "fast transfer scheme". The trip is through device 59VDU that functions as an undervoltage trip when Bus "D" is aligned to the 12kv Startup Bus. The 59VDU device has a setpoint of 72 volts secondary on a nominal 120 volt base. Since this relay serves a dual function as a permissive for the fast transfer scheme, it does not have a relay target or visual identifier that it has actuated. The review of the voltage profile obtained from the PDN an undervoltage condition confirmed that the 12kv bus voltage was degraded enough to drop out this 59VDU device and cause the trip of the load breakers associated with 12 kV Bus "D".

Alarms indicating CWP 2-1 differential trip and over current trips. These alarms appear to be cased by a fault downstream of breaker 52VD5. The breaker relay functioned as designed; however the bus “D” feeder breaker O/C relay did not trip. This indicates the fault current was greater than 800 amps, but less than 3200 amps.

Alarms for RCP 2-2 and 2-4 breaker open and Unit Reactor trip received. These alarms support the previous events.

Analysis of Events:

The 230kV and Auxiliary Power systems operated as designed
Unit 2 Bus “E” operated as designed
Unit 2 Bus “D” operated as designed.
The Unit 2 Reactor Trip sequence operated as designed.

Operating Experience

The loss of CWP 2-1 appears to be a failure of one or more surge capacitors. Review of NPRDS and EPIX databases identified approximately 6 events caused by capacitor failures. Discussions with PG&E personnel in the Transmission and Distribution department also identified past failures of surge capacitors. These events did not identify a common cause failure or corrective actions outside of replacement.

Extent of Condition:

Similar capacitors are found on the remaining CWPs, and large pumps such as the Heater 2 Drip Pumps and Condensate pumps. There are also several other electrical devices with capacitors, but not the same design as the surge capacitors. This extent of condition evaluation will focus on 12kV surge capacitors.

The surge capacitors on CWP 2-1 were replaced 4/93, on CWP 2-2 were replaced 2/98, on CWP 1-1 were replaced 3/94 and the age of the CWP 1-2 capacitors is unknown. The CWP 2-1, 2-2 and 1-1 motors all have 3 phase capacitors. The 1-2 motor has three single phase capacitors. The vendor of these capacitors (ABB) communicated that these capacitors have a 20 -30 year service life. Being that these capacitors are rated for 13.8 kV, there use in a 12 kV system will result in an even longer service life.

The PM for these capacitors consists of visually inspecting as part of routine motor inspections (1R). There is no time directed replacement. Routine thermography performed.

While the review of operating experience has been inconclusive, the input from the vendor indicates that the 2-2 and 1-1 surge capacitors are within their design life. The service life of the CWP 1-2 capacitors could not be determined. However, thermography and past inspections (for leaks and evidence of warm operation) have not identified any issues with these capacitors which has a different (less destructive) failure mode.

Based on review of previous inspection results for the CWP 2-1 capacitors, the failure of the CWP 2-1 is considered to be a random failure. Therefore, the conclusion of this extent of condition evaluation is that the probability of a similar event on the remaining CWP motors in the near future is low.

3. Apparent Cause Analysis

The apparent cause of the CWP 2-1 fault condition is failure of the surge capacitor. This surge capacitor initially had a ground fault that quickly turned into a phase to phase fault. This apparent cause is supported by the inspection of the termination box, personnel statements, relay actuation and voltage traces of the event.

There following are the facts that support the apparent cause statement above:

1. The following conditions were observed in the CWP 2-1 termination box.
Everything in the termination box is covered with heavy black soot from the fire.
The surge capacitor has been destroyed. The can has been split open and the terminations blown away. The internals are in the bottom of the termination box in the opposite corner.
The bus bar support frame and bus bars are damaged (bent and broken) from the direction of the capacitor.
The bus bars do not show any fault or arc damage.
There was a report of an explosion followed by smoke.
The annunciator logs associated with 12kV Bus “D” document alarms inputs 1917 (12kV Startup Transformer 2-1 Ground Overcurrent), 1306 (CWP 2-1 Differential Trip), 1306 (CWP 2-1 OC Trip) and 1902 (12kV Bus Undervoltage Trip).
PDN traces of the 12kV Bus “D” voltage transient showed that the voltage significantly dipped, which is indicative of a phase-to- phase fault.

4. Safety Analysis

Plant System Response:

For this event, plant systems must respond to 1) ensure the reactor is shutdown, and 2) decay heat removal is affected. The reactor protection system functioned as designed. RCP 2-2 and RCP 2-4 motor breakers opened on bus undervoltage. The RPS signal for this automatic reactor trip is 2 out of 4 RCP breakers open. Once the logic was satisfied, a trip signal was generated for the reactor trip breakers. Both breakers opened as required. Following the opening of the reactor trip breakers, all control rods (control and shutdown banks) fully inserted into the core, shutting down the Unit 2 reactor. Reactor coolant system pressure responded normally to this low power reactor trip; no pressurizer safety valves or power operated relief valves opened. Thus the reactor coolant system integrity was not compromised.

Decay heat removal from the reactor was maintained by using the auxiliary feedwater system and the 10 percent atmospheric steam dump valves. Immediately following the automatic reactor trip, operators manually initiated auxiliary feedwater to control water level for the steam generators. The 10 percent atmospheric steam dumps were opened periodically to control the temperature of the reactor coolant system, it turn controlling core decay heat.

Based on the operation of all safety components, the reactor was placed and controlled in a configuration that was within the design of the plant safety analysis per the UFSAR.

Safety Significance:

The safety significance of the event was assessed using an approach consistent with the NRC's Management Directive 8.3 process. Based on this evaluation it was concluded that the event can be characterized as a low safety significant event. The change in core damage probability (CCDP) for loss of condenser vacuum (LCV) is 8.16E-07*. The reason for the low significance is that the event itself was not a high consequence event and the fact that all the applicable accident mitigating systems performed as designed.

Since the condenser was unavailable, the event is an NRC Performance Indicator initiating event: “SCRAM with loss of normal heat removal.” The NRC’s white threshold for this PI is more than two over a three-year period. Given DCPP has not experienced a SCRAM while critical since 2002, margin for an additional event still exists on this PI.

5. Corrective Actions and Recommendations

On 12/13/06, PSRC met and agreed to the following actions:

Bus D 27VDT1: Clear Bus, Replace/Calibrate/Obtain As-Found & As-Left time delay relay.

Bus E Perform Extent of Condition assessment of time delay relay.

Develop PM, thermography inspection and/or replacement schedule for surge capacitors.

In addition, prior to the next PSRC Mode transition meeting, prepare OM4.ID2 “Mode Change Authorization” form, and present the OP1.DC1 Ops review.

On 12/14/06, PSRC met and agreed to remove the above 12/13/06 conditions based upon clarification that the startup power undervoltage protection scheme performed as designed during the event. Based upon discussion with the capacitor vendor the EIT concluded and the PSRC concurred that no increased monitoring is required. Also the root cause team for Nonconformance N0002214 will further address corrective actions.

6. References

A0684367 CWP 2-1 REPORT OF EXPLOSION AND FIRE
A0684370 UNABLE TO ACTIVATE UNIT 2 ERDS FOLLOWING NUE
A0684378 INSPECT 12 BUS 'D' AFTER CWP 2-1 INDUCED FORCED OUTAGE
A0684385 UNIT 2 REACTOR TRIP DUE TO CWP 2-1 FAILURE
A0684405 FIRE REPORT - CWP 2-1
A0664407 WHY DID THE HIGH PRESSURE C02 NOT ACTIVATE
A0684435 EVALUATE PRA RISK OF YELLOW W/ UNIT AT 50% & 1 CWP OOS
A0684495 27VDT1 ACTUATED EARLY
E-45 Supply Fan?
FCV-23 MSIV Bypass?
Step Counter?
N-35 HUNG UP AT 10 E-10 AMPS
A0684536 INCORRECT RELAY IDENTIFIED AS BEING ACTUATED
A0684535 AFW RISK ASSESSMENT FOR 2-1 STEAM SUPPLY

7. Attachments

See: J:\Icepics\Motors\CWP21